Electromagnetic and Beam Dynamics Studies for High Gradient Accelerators at Terahertz Frequencies

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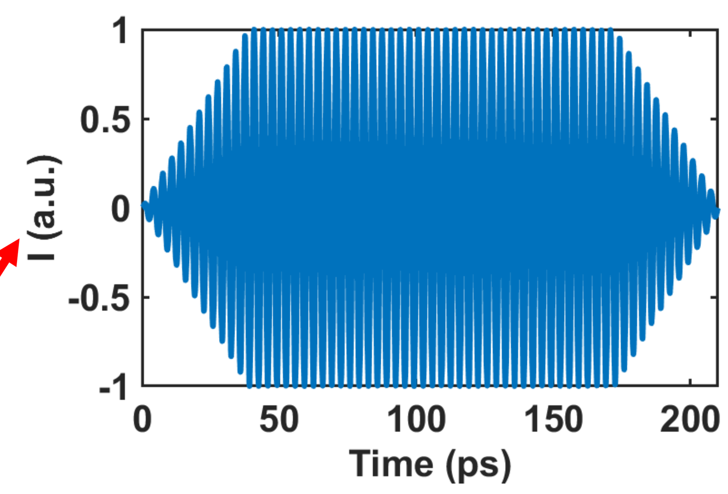
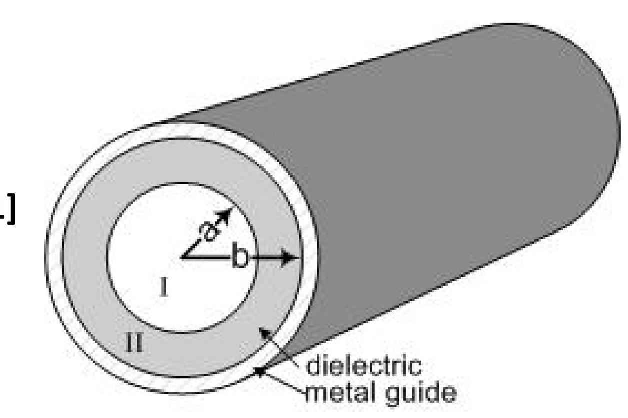
THz researches span from novel acceleration techniques for future linear accelerators, space applications, tunable optical devices, innovative materials, to new technologies for medical imaging, security and food and pharmaceutics controls. Conventional high brightness radio-frequency accelerating structures operate with 30-50 MV/m gradients; terahertz driven accelerating structures enable high-gradient electron accelerators (potentially up to the GV/m scale) with simple and compact accelerating structures. These compact terahertz accelerators hold great potential to have an impact for free electron lasers, linear colliders. Here we present electromagnetic and beam dynamics studies about the use of a dielectric loaded waveguide to accelerate electron bunches by mean of a narrow-band multi-cycle THz laser pulse. The excitation of the accelerating structure by the THz-pulse and the bunch acceleration in the excited field are investigated using CST Microwave Studio and GPT simulations.

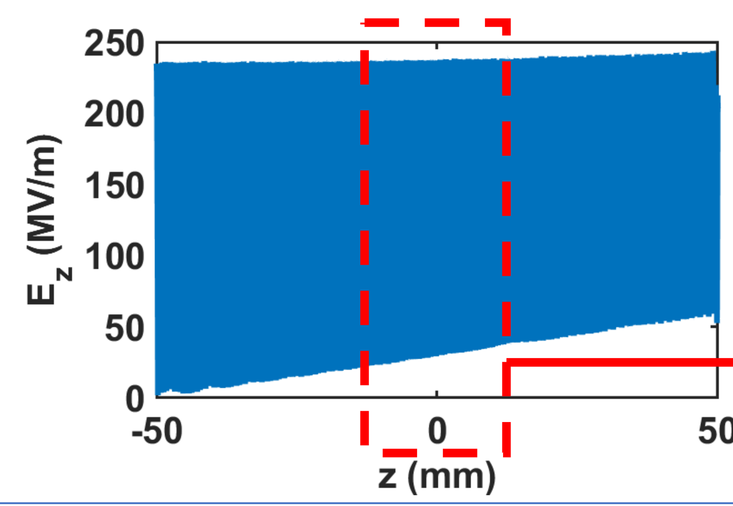
1. CST Electromagnetic Simulations

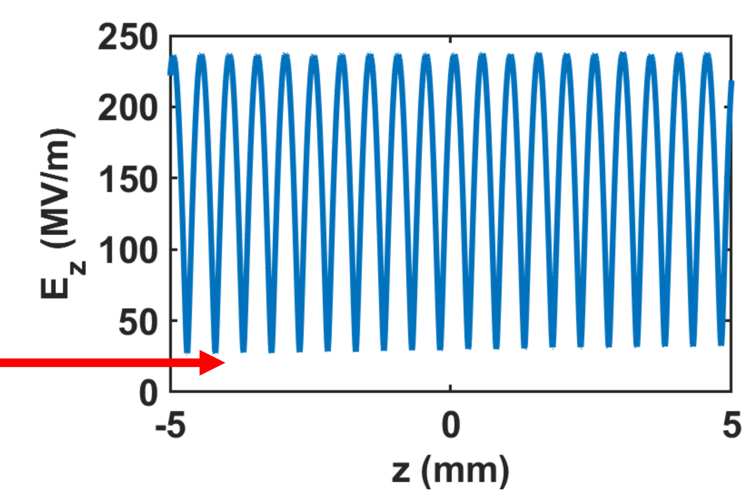
	$v_p = 1.003c$ [2] Structure 1	$v_p = c$ Structure 2
Frequency (f) (GHz)	300	300
Vacuum Radius (a) (μm)	625	624.3
Dielectric Thickness ($b-a$) (μm)	77.7	78.4
Dielectric Permittivity (ϵ_r)	4.41	4.41
Waveguide Length (L) (mm)	100	100
Iris Radius (μm)	100	100
Longitudinal Peak Field (MV/m)	240	240
Flat-top Laser Pulse (T) (ps)	133	133



[1]

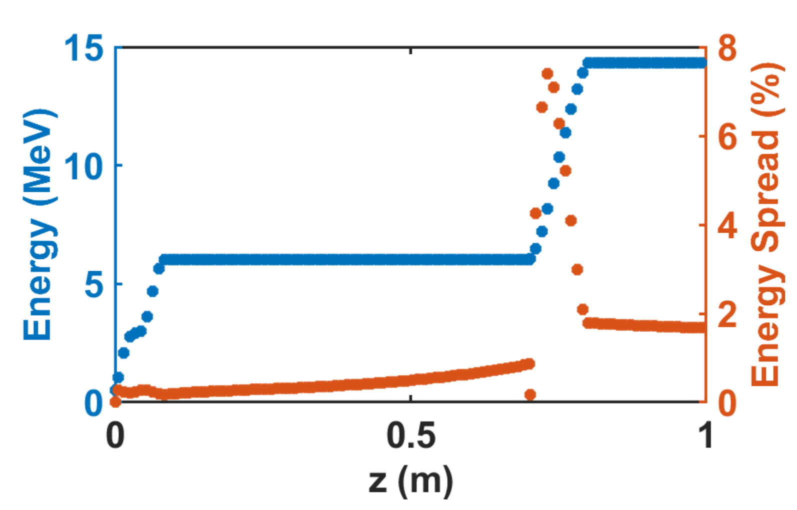




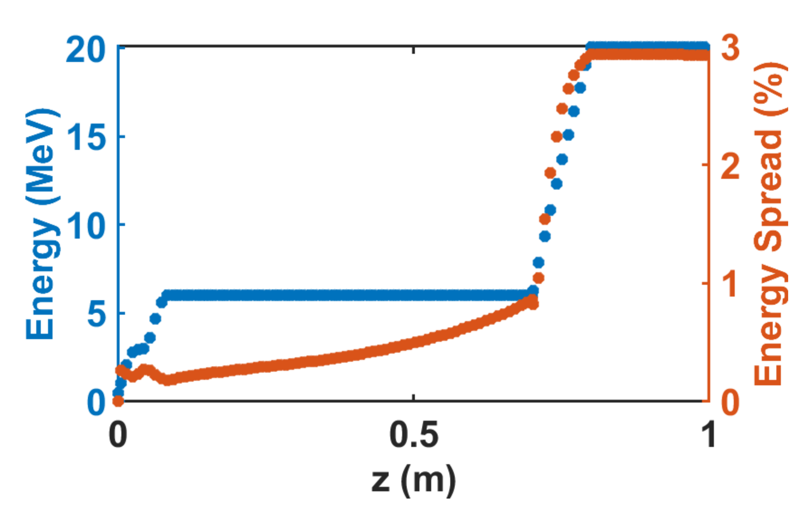


Simulations: GPT (Gun + THz Structure)

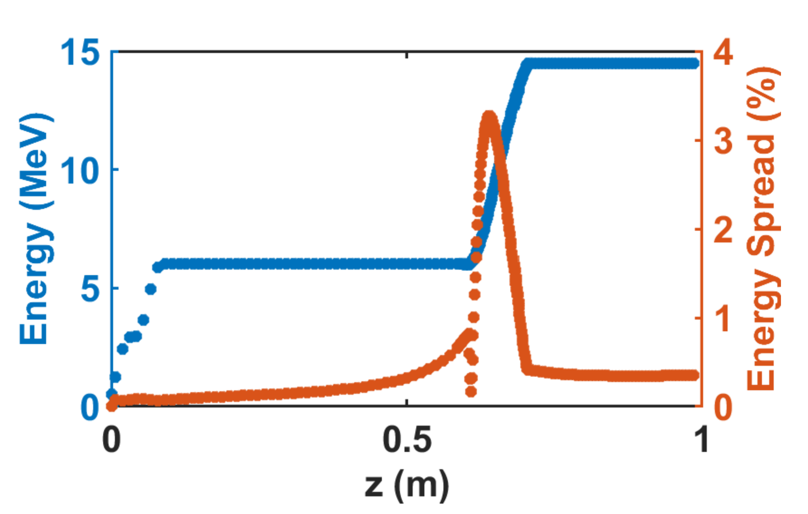
w.p.1 with THz structure 1



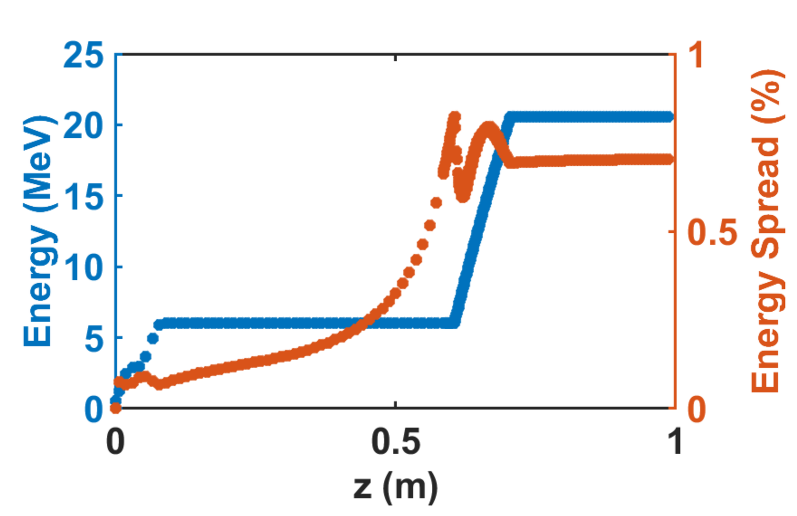
w.p.1 with THz structure 2



w.p.2 with THz structure 1



w.p.2 with THz structure 2



	w.p.1	w.p.2
Laser Length (fs)	155	72
Laser Radius (mm)	0.64	0.94
Charge (pC)	10	10
Thermal Emittance (mm ∗ mrad)	0.097	0.14
Structure Position (mm)	605	605
Beam Energy (MeV)	6 (0.8%)	6 (0.8%)
Beam Spot (μm)	25	25
Bunch Length (μm)	**44**	**20**
Beam Emittance (mm ∗ mrad)	0.28	0.76

w.p.1 f.b.m.	Structure 1	Structure 2
Beam Energy (MeV)	14 (1.8%)	20 (2.9%)
Beam Spot (μm)	19	24
Bunch Length (μm)	29	46
Beam Emittance (mm ∗ mrad)	0.28	0.28
Average Gradient (MV/m)	**83**	**141**

w.p.2 f.b.m.	Structure 1	Structure 2
Beam Energy (MeV)	14 (0.4%)	21 (0.7%)
Beam Spot (μm)	29	27
Bunch Length (μm)	14	21
Beam Emittance (mm ∗ mrad)	0.8	0.78
Average Gradient (MV/m)	**85**	**145**

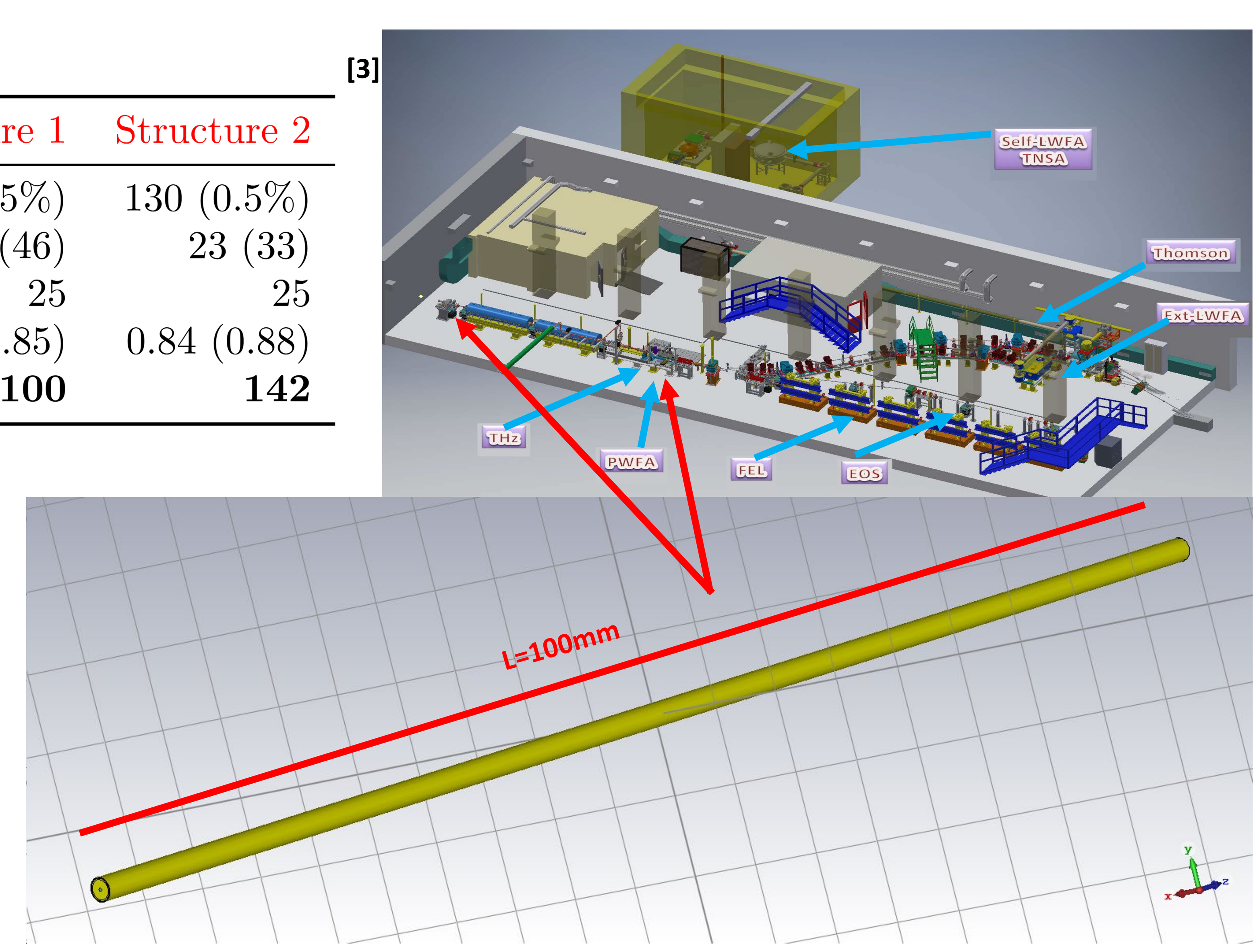
Legend:
w.p. = working point
f.b.m. = final beam parameters

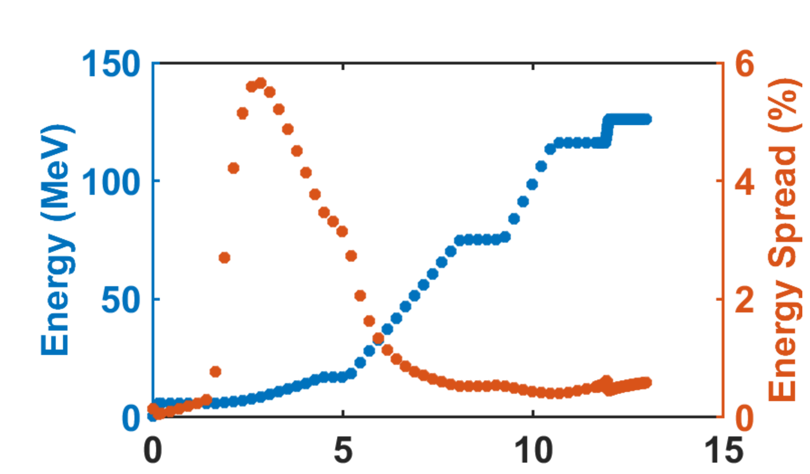
Simulations: GPT (SPARC Linac + THz Structure)

	w.p.3
Laser Length (ps)	6
Laser Radius (mm)	0.51
Charge (pC)	100
Thermal Emittance (mm ∗ mrad)	0.142
Structure Position (m)	11.88
Beam Energy (MeV)	116 (0.6%)
Beam Spot (μm)	61 (41)
Bunch Length (μm)	25
Beam Emittance (mm ∗ mrad)	0.84 (0.88)

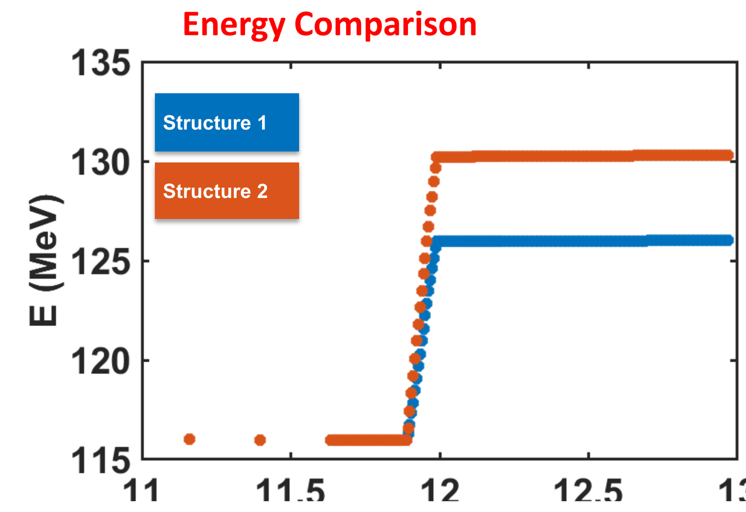
w.p.3 f.b.m.	Structure 1	Structure 2
Beam Energy (MeV)	126 (0.5%)	130 (0.5%)
Beam Spot (μm)	39 (46)	23 (33)
Bunch Length (μm)	25	25
Beam Emittance (mm ∗ mrad)	0.90(0.85)	0.84 (0.88)
Average Gradient (MV/m)	**100**	**142**

[3]





Energy Comparison



References

[1] Jing C., et al. "Dielectric Wakefield Accelerator to Drive the Future FEL Light Source", ANL/APS/LS-326 March 21, 2011
[2] Galaydych K., et al. "Simulation of an Electromagnetic Field Excitation by a THz-Pulse and Acceleration of an Electron Bunch in a Dielectric-Loaded AXSIS Linac", Proceedings of IPAC2017, Copenhagen, Denmark
[3] M. Ferrario, et al., "*SPARC_LAB present and future*", NIM A, 2013

Acknowledgements

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